IN THE TITLE:

Please amend the title to read as follows: --A PROJECTION APPARATUS FOR PROJECTING A PATTERN FORMED ON A MASK ONTO A SUBSTRATE AND A CONTROL METHOD FOR A PROJECTION APPARATUS--.

IN THE ABSTRACT

Please cancel the Abstract and replace it with the following new Abstract:

A1

--A projection apparatus includes a charged particle beam source, a reduction lens, a charged particle shaping aperture having an arcuate opening, a collimator lens, and first and second projection lenses. A charged particle beam emerging from the charged particle beam source irradiates a mask placed on a mask stage to transfer a pattern on the mask onto a sample on a sample stage. The first and second projection lenses can move their first and second principal plane positions with an excitation strength ratio control circuit.--.

IN THE SPECIFICATION:

Please amend the specification as follows:

Please substitute the following paragraph for the paragraph starting at page 1, line 15 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A2

Conventionally, in mass production of semiconductor memory devices, an optical stepper having high productivity has been used. In the production of new-generation memory devices

from 1G- and 4G-DRAM memory devices having a line width of 0.2 μm or less, the high-productivity charged particle beam exposure method having high resolving power and using charged particles, e.g., electrons or ions, is a promising technique that replaces the optical exposure method.

Please substitute the following paragraph for the paragraph starting at page 2, line 10 and ending at line 24. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In recent years, a cell projection method has been proposed as one method that solves this problem. According to this method, the repeated portion of the memory circuit pattern is divided into cells each having several μm regions, and the pattern is exposed in units of cells. With this method, the maximum region that can be exposed at once has a size as small as about several μm. A plurality of deflectors are used to enlarge the exposure region. As the exposure region becomes large, deflection aberrations increase. These deflection aberrations are eliminated by dynamic correction using focus coils and stigmators. This method can enlarge the maximum region that can be exposed at once. However, it takes a comparatively long period of time till the deflected electron beam is settled at a desired position. This decreases the productivity.

Please substitute the following paragraph for the paragraph starting at page 2, line 25 and ending at page 3, line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

An electron beam projection exposure method is under development which does not require a time for settling the electron beam. The projection system of an apparatus of this type uses a symmetric magnetic doublet lens. Also, an aperture for separating scattered electrons and unscattered electrons at the pattern portion and mask membrane portion, respectively, of the transfer mask from each other is arranged at a position that divides the distance between the mask and a photosensitive member in accordance with the magnification ratio. The positions of the principal planes of the two magnetic lenses of the magnetic lens are respectively set between the mask and the aperture, and at the intermediate position of the distance between the aperture and a sample coated with the photosensitive member. The two magnetic lenses can move only a small distance when they are mechanically adjusted. According to the electron beam projection exposure method, the pattern to be transferred onto the sample is divided into a plurality of partial patterns, and the divided partial patterns are formed on a mask. While an electron beam irradiates a selected partial pattern on the mask, the mask and sample are continuously moved in opposite directions. An electron beam transmitted through the mask irradiates the sample, thereby exposing the sample. Since this method does not perform electron beam scanning, it does not take much time to settle the electron beam. As a result, this method has a higher productivity than other methods described above.

Please substitute the following paragraph for the paragraph starting at page 4, line 18 and ending at page 5, line 7. A marked-up copy of this paragraph, showing the changes made thereto is attached.

B5

According to the first aspect of the present invention, there is provided a projection apparatus for projecting a pattern formed on a mask held by a mask stage onto a sample on a sample stage and transferring the projected pattern, comprising a charged particle beam source, a shaping system for shaping a charged particle beam emerging from the charged particle beam source to have an arcuate cross-section, a projection optical system including a projection lens including a pair of magnetic lenses, the projection optical system being located between the shaping system and the sample stage, a driver for supplying excitation currents to the pair of magnetic lenses to drive the projection lens, and a controller for controlling the ratio of the currents to be supplied from the driver to the pair of magnetic lenses to move the position of a principal plane of the projection lens.

Please substitute the following paragraph for the paragraph starting at page 5, line 8 and ending at line 12. A marked-up copy of this paragraph, showing the changes made thereto is attached.

B6

In the projection apparatus according to the first aspect of the present invention, for example, the controller preferably controls the ratio of the currents to be supplied from the driver to the pair of magnetic lenses so as to correct image distortion of the projection optical system.

Please substitute the following paragraph for the paragraph starting at page 5, line 13 and ending at line 24. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a7

In the projection apparatus according to the first aspect of the present invention, for example, the projection optical system preferably includes a second projection lens including a pair of magnetic lenses to which excitation coil currents are supplied from the driver, and the controller preferably controls the ratio of the currents to be supplied from the driver to the pair of magnetic lenses of the second projection lens to move the position of the principal plane of the second projection lens so as not to change an image position and magnification of the projection optical system when correcting image distortion of the projection optical system by controlling the first projection lens.

Please substitute the following paragraph for the paragraph starting at page 5, line 25 and ending at page 6, line 7. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a8

In the projection apparatus according to the first aspect of the present invention, for example, the projection apparatus preferably further comprises acquisition means for acquiring image information indicating a feature of an image projected onto the sample stage by measurement, and the controller preferably controls the ratio of the currents to be supplied to the pair magnetic lenses so as to correct the image distortion of the projection optical system on the basis of the image information.

Please substitute the following paragraph for the paragraph starting at page 6, line 8 and ending at line 13. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a9

In the projection apparatus according to the first aspect of the present invention, for example, the image information preferably contains information indicating the radius of an image formed on the sample stage with the arcuate cross-sectional charged particle beam emerging from the shaping system.

Please substitute the following paragraph for the paragraph starting at page 6, line 14 and ending at line 19. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a10

In the projection apparatus according to the first aspect of the present invention, for example, the controller preferably controls the ratio of the currents to be supplied to the pair of magnetic lenses, so that the measured radius coincides with the theoretical radius obtained when the projection optical system has no aberration.

Please substitute the following paragraph for the paragraph starting at page 6, line 20 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a11

In the projection apparatus according to the first aspect of the present invention, for example, the image information is preferably information indicating the an image height of an image formed on the sample stage with the arcuate cross-sectional charged particle beam that has passed through the shaping system.

Please substitute the following paragraph for the paragraph starting at page 7, line 1 and ending at line 7. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a12

In the projection apparatus according to the first aspect of the present invention, for example, the controller preferably controls the ratio of the currents to be supplied to the pair of magnetic lenses, so that the actually measured image height coincides with the theoretical image height obtained when the projection optical system has no aberration.

Please substitute the following paragraph for the paragraph starting at page 8, line 5 and ending at line 13. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a13

In the projection apparatus according to the first aspect of the present invention, for example, the acquisition means preferably calculates the radius of an image projected onto the sample stage on the basis of a plurality of measured coordinates, and the controller preferably controls the ratio of the currents to be supplied from the driver to the pair of magnetic lenses, so that the radius obtained by measurement coincides with the theoretical radius obtained when the projection optical system has no aberration.

Please substitute the following paragraph for the paragraph starting at page 9, line 7 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

According to the second aspect of the present invention, there is provided a control method for a projection apparatus having a mask stage for holding a mask, a sample stage for placing thereon a sample on which a pattern formed on the mask is to be projected and transferred, a charged particle beam source, a shaping aperture for shaping a charged particle beam emerging from the charged particle beam source to have an arcuate cross-section, a projection optical system including a projection lens including a pair of magnetic lenses, the projection optical system being located between the shaping system and the sample stage, and a driver for supplying excitation currents to the pair of magnetic lenses to drive the projection lens, comprising the acquisition step of acquiring correction information necessary for correcting the aberration of the projection optical system, and the control step of controlling the ratio of the currents to be supplied from the driver to the pair of magnetic lenses (doublet lens) to move the position of a principal plane of the projection lens.

a14

Please substitute the following paragraph for the paragraph starting at page 10, line 1 and ending at line 5. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a15

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the control step preferably comprises correcting image distortion of the projection optical system on the basis of the correction information.

Please substitute the following paragraph for the paragraph starting at page 10, line 6 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A16

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the projection optical system preferably includes a second projection lens including a pair of magnetic lenses (doublet lens) to which excitation currents are supplied from the driver, and the control step preferably comprises controlling the ratio of the currents to be supplied from the driver to the pair of magnetic lenses of the second projection lens to move the position of a principal plane of the second projection lens so as not to change an image position and magnification of the projection optical system when correcting image distortion of the projection optical system by controlling the first projection lens.

Please substitute the following paragraph for the paragraph starting at page 10, line 19 and ending at page 11, line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A17

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the acquisition step preferably includes the measurement step of acquiring by measurement image information indicating a feature of an image projected onto the sample stage as the correction information, and the control step preferably comprises correcting image distortion of the projection optical system on the basis of the image information.

Please substitute the following paragraph for the paragraph starting at page 11, line 3 and ending at line 8. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a18

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the image information preferably contains information indicating the radius of an image formed on the sample stage with the arcuate cross-sectional charged particle beam emerging from the shaping system.

Please substitute the following paragraph for the paragraph starting at page 11, line 16 and ending at line 21. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a19

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the image information is preferably information indicating the image height of an image formed on the sample stage with the arcuate cross-sectional charged particle beam that has passed through the shaping system.

Please substitute the following paragraph for the paragraph starting at page 12, line 3 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

a20

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the mask stage is preferably arranged between the shaping system and the projection optical system, the acquisition step preferably comprises the preparation step

of causing the mask stage to hold an image distortion measurement mask having a transmitting system that passes therethrough a predetermined portion of the arcuate cross-sectional charged particle beam emerging from the shaping system, the measurement step of measuring coordinates of a position where the charged particle beam that has passed through the transmitting system becomes incident on the sample stage, and the calculation step of calculating, as correction information necessary for correcting image distortion of the projection optical system, image information indicating a feature of an image projected onto the sample stage on the basis of the measured coordinates, and the control step preferably comprises controlling the ratio of the currents to be supplied from the driver to the pair of magnetic lenses to move the position of a principal plane of the projection lens so as to correct image distortion of the projection optical system on the basis of the correction information.

A20 Cont'd.

Please substitute the following paragraph for the paragraph starting at page 13, line 9 and ending at line 19. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A21

In the control method for the projection apparatus according to the second aspect of the present invention, for example, the calculation step in the acquisition step preferably comprises calculating a radius of an image projected onto the sample stage on the basis of a plurality of measured coordinates, and the control step preferably comprises controlling the ratio of the currents to be supplied from the driver to the pair of magnetic lenses, so that a radius obtained by measurement coincides with a theoretical radius obtained when the projection optical system has no aberration.

Please substitute the following paragraph for the paragraph starting at page 21, line 7 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the charged particle beam projection system, the image distortion amount measurement mask 50 is mounted on the mask stage 8 before exposure of the sample 12, and the image distortion amount is measured by using the mask 50. The image distortion amount measurement mask 50 is formed with a plurality of rectangular small punched patterns for passing the arcuate cross-sectional charged particle beams therethrough. The positions of the punched patterns are measured with high precision in advance and are thus known. In Fig. 4, the rectangular holes 51, 52, and 53 are formed as three punched patterns, and their coordinate positions are known, i.e., (x1, y1), (x2, y2), and (x3, y3).

R22

Please substitute the following paragraph for the paragraph starting at page 26, line 16 and ending at page 28, line 4. A marked-up copy of this paragraph, showing the changes made thereto is attached.

An embodiment of a device manufacturing method utilizing the charged particle beam projection apparatus described above will be described. Fig. 7 shows the flow chart of the manufacture of a microdevice (a semiconductor chip such as an IC or LSI, a liquid crystal panel, a CCD, a thin film magnetic head, a micromachine, or the like). In step 101 (circuit design), the device pattern is designed. In step 102 (mask fabrication), a mask formed with the designed pattern is fabricated. In step 103 (wafer manufacture), a wafer is manufactured by using a material such as silicon or glass. Step 104 (wafer process) is called a pre-process. An actual

R23

circuit is formed on the wafer in accordance with lithography by using the prepared mask and wafer. Next step 105 (assembly) is called a post-process. The wafer fabricated by step 104 is formed into semiconductor chips. Step 105 includes steps such as an assembly step (dicing and bonding) and a packaging step (chip encapsulation). In step 106 (inspection), the semiconductor device fabricated in step 105 is inspected by an operation confirmation test, a durability test, and the like. The semiconductor device is completed through these steps, and is shipped (step 107). Fig. 8 shows the flow chart of this wafer process in detail. In step 111 (oxidation), the surface of the wafer is oxidized. In step 112 (CVD), an insulating film is formed on the surface of the wafer. In step 113 (electrode formation), electrodes are formed on the wafer by vapor deposition. In step 114 (ion implantation), ions are implanted in the wafer. In step 115 (resist process), a resist is applied to the wafer. In step 116 (exposure), the circuit pattern of the mask is baked on the plurality of shot regions of the wafer, and exposed in accordance with the exposure apparatus or method described above. In step 117 (development), the exposed wafer is developed. In step 118 (etching), a portion other than the developed resist image is removed. In step 119 (resist separation), the resist no longer necessary after etching is removed. These steps are repeatedly performed to form multiple circuit patterns on the wafer. When the production method of this embodiment is used, a large-size device, which is conventionally difficult to manufacture, can be manufactured at a low cost.

IN THE CLAIMS:

Please amend Claims 1-9, 11, 12, 15, 17-23, 25 and 29 as follows. A marked-up copy of Claims 1-9, 11, 12, 15, 17-23, 25 and 29 showing the changes made thereto, is attached. Note